SAFETY REQUIREMENTS & TRANSPORT OF DANGEROUS GOODS THROUGH THE 53 KILOMETER RAILWAY TUNNEL THROUGH THE ALPS BETWEEN LYON AND TURIN

Verbisselt E.¹, Nieuwenhuis J.E.², Lezwijn S.A.²
¹Lyon-Turin Ferroviare, France
²ARCADIS, The Netherlands

ABSTRACT

This project concerns the border crossing part of the new high speed link between Lyon and Turin. This high speed link is an important connection in the pan-European railway network. In 2015 the first trains will run. The tunnel will be used by high speed passenger trains, freight trains and “Autoroute Ferroviaire” (trucks on the train). ARCADIS has studied the transport of dangerous goods and the functional requirements of the safety equipment.

Keywords: transport of dangerous goods, tunnel safety, railway tunnel

1. INTRODUCTION

The Lyon-Turin rail link between France and Italy, crossing the Alps, is one of the major projects in Europe. This high speed link is an important connection in the pan-European railway network. In 2015 the first trains will run. The link will be used by high speed passenger trains, freight trains and “Autoroute Ferroviaire” (trucks on the train) and will consist of a 53 km long tunnel crossing the border between France and Italy as well as the 12 km long Bussoleno tunnel. For such a project, the safety expectations are very high. Before starting the detailed design of the tunnel, it is therefore of importance which safety measures are to be integrated in the tunnel to meet the defined safety principles.

2. EQUIPMENTS

In order to provide for the required level of safety in the tunnel, several security systems and security equipment has been foreseen in both tunnels (Tunnels du base and the Tunnels du Bussoleno).

2.1. Emergency philosophy

The emergency philosophy for trains with a fire onboard has to, if possible, continue to a ‘safe haven’ and to evacuate all passengers there. For all other trains not directly involved in the incident the rule is to a) leave the tunnel(s) as quickly as possible or to b) stop before entering the tunnel.

2.2. Emergency installations and equipments

The following emergency installations are used in the tunnel and connected areas:

- Detection equipment for:
  - Smoke and fire
  - Derailment
  - Train stop
  - Gage
  - Fumes and gasses
- Containment and extinguishing equipment in case of fire:
  - Ventilation systems in tunnels, inter tube tunnels
  - Ventilation of safe areas
  - Ventilation of technical rooms

- Control systems:
  - Lighting system
  - Video system (CCTV)
  - Central command post (PCC)
  - Communication equipment
  - Telephone system
  - HF communication system

The following equipment is foreseen in the tunnels, intervention stations and safety stations and surrounding elements:

- Evacuation of passengers:
  - Emergency platforms:
    - In the tunnels (min. 1.2 m width)
    - In the emergency stations and station (3.0 m width, 750 m length)
    - Cross passages (every 400 m, in Modane station every 50 m)
    - Collection rooms for the injured in every intervention and emergency station
    - Directions signs for emergency escapes
    - Audio system

- Accessibility and equipment for emergency services:
  - Emergency accesses at the highest point of every emergency tunnel, connecting to local infrastructure. The accesses are provided with a helicopter platform, parking space, and a command post
  - Emergency tunnels
  - Fire extinguishing equipment:
    - Hydrants (6 – 10 bar, every 133 m, French and Italian system)
    - Fire mitigation system in every intervention station and in the safety station
    - Automatic fire extinguishing system in technical rooms
    - Emergency water reservoirs (with a capacity of 120 m³) in each station.
    - Central command post (PCC), one in France and one in Italy.
    - Drainage system liquids (alpine water, extinguishing water)
    - Storage tanks for dangerous liquids (6 in total, storage capacity 240 m³ per tank)

Three systems in particular will be described in following paragraphs, namely the foam water system, the emergency tunnels and the drainage system.

2.3. Fire mitigation system

Fires with a capacity of 50MW can occur in the tunnel, due to the properties of transported goods and air speeds in the tunnel. These fires cannot be reached physically by fire fighters and therefore cannot be put out in a traditional way. For this reason, all goods trains will have to make a safety stop at an intervention station or safety station when exiting the tunnel is not an option. Each intervention and emergency station in the tunnel is provided with a sprinkler like system, using a specific mixture with water onto the fire from nozzles located on either side of the tunnel roof. Two systems have been modelled and tested: a Foam Water system and a high pressure Water Mist system. With a ventilation speed of 2 m/s, the following results are found.
The figure shows that the FW system reduces a fire to 20% of its original intensity within 70sec and to 10% within 150sec. The WM system mitigates a fire to 40% and 35% for the same time intervals respectively. These results are obtained when the system is called into action immediately after the start of a fire. There are however scenarios in which it takes up to 15 min before a train is located in an intervention station provided with a FM or WM system and the system is switched on. This way, 100MW fires cannot be excluded.

![Graph showing HRR (Heat Release Rate) over time for FW and High Pressure WM systems.](image)

Figure 1: Test results from Foam Water and high pressure Water Mist systems to a 50MW fire.

2.4. Emergency tunnels

The intervention stations of Saint-Martin, La Praz and Venaus, as well as the emergency station of Modane are connected to the outside world by means of emergency tunnels. In total there are 4 emergency tunnels, with a diameter of 10m and lengths varying from 500 to 4,500m. The emergency tunnels will be used by emergency services in case of an emergency. The enormous length of the emergency tunnels led resulted in a one-way regime for traffic, with passage sites every 400m, dividing each emergency tunnel into sections. The passage sites have a length of 200m and a width of 20m. Traffic lights will be used to indicate a free passage per section.

2.5. Drainage system

In the tunnel, a drainage system is applied to drain the alpine water from the tunnel the slope of the system is 2%, following the tunnel slope. In case of fire in a goods train leaking dangerous liquids, extinguishing efforts with water will result in a pool fire, possibly increasing the capacity of a fire. Therefore, the drainage system consists of lateral and longitudinal canals that collect in central collection points with siphons, to prevent progression of a fire in the closed drainage system. The liquids are collected in storage tanks, located at every station and at the heads of the tunnel.

3. DANGEROUS GOODS

One of the reasons the tunnels are being constructed is the transport of freight. From current transport of freight we know that a substantial part of the international transport can be classified as dangerous goods. Effects of an incident with dangerous goods in the tunnel may be serious for both persons present and the structure of the tunnel. Before allowing transport of dangerous goods in the tunnel, it has to be determined whether the possibility of an accident in relation to the effects is acceptable.
3.1. The methodology

The UN working group WP15 on the transport of dangerous goods has been developing a methodology to categorize tunnels. Through tunnels of different categories, different groups of dangerous goods are allowed for transport. For the LTF project this methodology has been the base to define safety measures and to determine whether transport of dangerous goods can be allowed in the tunnels. For each group is determined whether the possibility of an accident in relation to the effects is acceptable and if safety measures can be taken to ensure that the required safety level is reached.

3.2. Possible effects and proposed safety measures

3.2.1. Group A

Dangerous goods in this group are prohibited for transport and are therefore not analyzed in the studies for the project Lyon Turin Ferroviaire.

3.2.2. Group B

3.2.2.1 The effects

Dangerous goods in this group can provoke a big explosion. LPG is the product most transported good within this group. For this reason the effects of an accident with LPG are taken as normative to analyze the effects of a possible incident with goods of this group. Two types of incidents have been considered: a leak of limited size leading to a vapour cloud explosion after ignition and a catastrophic failure of a LPG vessel leading to a BLEVE (Boiling Liquid Expanding Vapour Explosion). A combination of a steady leak and steady ventilation flow may result in a homogeneous cloud in the tunnel downstream of the leak. For stoichiometric clouds of 10, 20, 50 and 100 meter length (it is never certain when a cloud may be ignited), the blast effects up to a distance of 5000 meters on either side of the cloud have been modelled.

![Figure 2: The blast effects after ignition of a cloud with a length of 100 meter](image)
A vapour cloud explosion as simulated can generate a blast that can cause victims up to 4200 metres.

![Figure 3: Possible blast after a BLEVE of a vessel of 100m3](image)

The blast of the simulated BLEVE can cause victims up to a distance of 4200 meters in the tunnel on both side of the incident.

### 3.2.2.2 Proposed safety measures

The prognostics show a large amount of possible transport of flammable gases. For this reason, both protective and preventive measures are proposed for the tunnel.

Since effects of an explosion reach up to 4200 meters in the tunnel, the first measures is to keep a distance of at least 4200 meters between a train carrying this products and a train with passengers. Furthermore the truck train combination is not allowed for this group since there are too many drivers present in the train, thus within the 4200 m range.

### 3.2.3. Group C

#### 3.2.3.1 The effects

Dangerous goods in group C are goods that can provoke an explosion or a toxic leak in the tunnel. To analyse possible effects of possible incident with goods in this group, dispersion of ammonia and chloride in the tunnel is modelled.
Figure 4: Dispersion of chloride in the tunnel after a leak (50mm) of a vessel (ventilation speed 3 m/s).

With the probit function (probit functions give the mortality rate depending on concentration and exposure time) for chloride it is calculated the toxic cloud reaches up to 3500 meters from the incident after 16 minutes.

Figure 5: Dispersion after a leak (50mm) of ammonia (taken ventilation speed 3 m/s).

The lethal concentration of ammonia will not reach as far as the chloride cloud.

Toxic vapour clouds from toxic liquids have also been analysed. Since evaporation from a liquid pool is a lot slower than evaporation of a pressurized gas, effects will not carry as far as the effects of pressurized gases.
3.2.3.2 Proposed safety measures

Since some of the goods in this group can provoke an explosion, a distance of at least 4200 meters (3500 m for truck-trains) between a train carrying this products and a train with passengers is introduced.

To reduce toxic effect of gases, the ventilation system should be able to influence the velocity and the direction of a toxic cloud.

To reduce the effect of toxic liquids it is proposed to limit the surface of a possible pool to minimise evaporation. As for the flammable liquids a maximum of 100m² is proposed (see above). The evacuation system has the possibility to separate toxic liquids and water (they can provoke a chemical reaction in some cases).

Further on, the ventilation systems of trains passing through the tunnel should be closed unless toxic clouds can be detected before trains with groups of passengers enter the tunnel.

The Sonia vehicle does also have this possibility to ensure that drivers of the trucks can get away in this vehicle.

3.2.4. Group D

3.2.4.1 The effects

Dangerous goods in groups D are those that can provoke a major fire. To analyse possible effects of possible incident with goods in this group, the effects of a fire of 100 and 200 MW in the tunnel have been modelled.

Figure 6: Temperature of 100MW in relation to distance in the tunnel.
Furthermore the effect of a fire in case of another train present was analysed.

![Figure 7: simulation of a major fire next to a passenger train](image)

It has been concluded that the temperature reaches up to 50 °C at 3500 meter after 15 minutes. Since the air in the tunnel will be moist, this the level which can be dangerous to persons present in the tunnel.

3.2.4.2 Proposed safety measures

Since temperature and smoke can reach dangerous levels up to a distance of 3500 meters, this distance should be kept between a train carrying flammable products and a train with passengers. The interdistance of 4200 m caused by group B makes this one oblivious.

To prevent a fire from growing too fast and to limit effects, the ventilation system should be able to influence the velocity and the direction of the air in the tunnels.

To make sure a pool fire will be limited in magnitude, the surface of a possible pool should be limited to a maximum of 100m² (gasoline generates about 2 MW/m²).

The Sonia vehicle must be able to leave as fast as possible after an incident, before the effects of a fire reach the vehicle where the drivers are present.

3.2.5. Group E

Since the products in group E are either less dangerous or transported in smaller quantities this group has not been analysed. Measures taken to reduce risks for the other groups are supposed to be efficient enough to take away the risks of this group.

4. CONCLUSION

- The safety studies have been carried out in order to determine the Functional Requirements Specifications of all safety measures and precautions in the tunnels to minimize the risks.
- The outcomes are input for further technical studies of the project as well as for the definition of the layout and design of the tunnel. It is up to the design engineers to incorporate all proposed measures in the tunnel.